Abstract Title Page

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Title: Preliminary Analysis of a Randomized Trial of Computer Attention Training in Children with Attention-Deficit/Hyperactivity Disorder

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Abstract Body

Limit 5 pages single spaced.

Background / Context:

Description of prior research and its intellectual context.

Attention Deficit/Hyperactivity Disorder (ADHD) is a neurologically-based behavioral disorder whose core symptoms include hyperactivity, impulsivity, and distractibility/inattention. ADHD is also highly associated with executive function deficits such as working memory, processing information, developing strategies, and organizing and executing tasks (Barkley, R.A., 1997; Clark, C., Prior, M., & Kinsella, G.J., 2000). Children with ADHD often have other comorbid problems such as oppositionality, aggression, anxiety, and specific learning disabilities (Kadesjo & Gillberg, 2001; Newcorn, Jeffrey, Halperin, Jeffery, Jensen, et al. 2001; Wolraich, Hannah, Baumgaertel, & Feurer, 1998; Pliska, 1998).

Estimates of the prevalence of ADHD range from 4 to 10%. Up to 80% of children with ADHD exhibit problems with academic performance (Cantwell & Baker, 1991) including difficulties with development of core reading (DuPaul & Stoner, 2003) and writing composition skills (Reid & Linemann, 2006). Math skills, including difficulties with problem conceptualization, basic facts retrieval, and speed of computational performance are also affected (Mautone, DuPaul, & Jitendra, 2005; Zentall & Ferkis, 1993). As a result, children with ADHD score significantly lower on reading and arithmetic achievement tests than controls (Biederman, et al, 1996). Moreover, they tend to perform at a lower academic level than would be predicted given their intellectual abilities, and the severity of their symptoms predicts the degree of academic impairment in reading, mathematics and writing (DeShanzo-Barry, Lyman, & Klinger, 2002). High rates of off-task and disruptive behavior displayed by children with ADHD often occur in school settings, both in the classroom and on the playground.

Many studies have demonstrated the efficacy of medication and/or behavior therapy for the treatment of the core symptoms of ADHD (MTA Cooperative Group, 1999). Based on this evidence, most professional medical and psychological societies recommend a combination of medication and behavior therapy for treating ADHD in school-age children (Conners, March, Frances, Wells, & Ross, 2001; National Institute of Health, 2000; AACAP, 2007). While these treatments are important and viable options for families of children with ADHD, they are also associated with significant limitations. These limitations highlight the importance of continuing to research alternative treatments for ADHD.

Computer-based attention-training interventions for children with ADHD are based on the theory of operant conditioning (Sterman, 1996; Lubar, 1997). Participants engage in targeted cognitive exercises while the software reinforces desirable behaviors (e.g., on-task behaviors and correct answers) and punishes non-desirable behaviors (e.g., off-task or impulsive behaviors) via auditory and visual feedback (e.g., beeps, buzzers, increase or decrease in score). Computer-based attention-training interventions can be separated into two main types that vary in their method of reinforcement: (1) those that rely on neurofeedback (NFB) to detect and reinforce behaviors that are associated with increased attention, as evidenced by specific brainwave patterns; and (2) those that use a Standard Computer Format (SCF) with specifically designed exercises to train children's attention using on-going computer-based feedback to reinforce correct responses and decrease impulsivity. Based on the theory of operant conditioning, computer-based interventions are designed to decrease ADHD symptomatology, and improve skills that are typically deficient in children with ADHD. These strengthened abilities enable children with ADHD to show improvements in classroom behavior and academic outcomes.

The rationale for neurofeedback is based on findings that EEG patterns differ between children with and without ADHD. Quantitative electro-encephalographic (QEEG) scans of children with ADHD display differences in brain activity, such as increased frontal lobe low frequency theta activity (associated with drowsiness; Mann, Lubar, Zimmerman, Miller, & Muenchen, 1992; Chabot & Serfontein, 1996; Monastra et al, 1999; El-Sayed, Larsson, Persson, & Rydelius, 2002), and a decrease in high-frequency beta wave activity (associated with a state of alert attention; Mann et al, 1992; Chabot & Serfontein, 1996; Monstra, Lubar, & Linden, 2001). The underlying principle of this system recognizes that intentional cortical self-regulation is possible through operant conditioning.

Several studies suggest that attention training using neurofeedback may result in decreased symptoms of ADHD and improved academic performance and behavior at school. In one such study of 100 children on stimulant medication (Monastra, Monastra, & George, 2002), only the participants who received additional neurofeedback sustained the positive gains after the stimulant medication was discontinued. A small randomized controlled trial of neurofeedback with a waitlist control (Linden, Habib, & Radojevic, 1996), demonstrated improvements in behavioral symptoms of ADHD. Unfortunately, there were only 18 participants, so there was insufficient power to demonstrate a statistically significant difference between the groups.

Attention-training systems with SCF use a standard computer, mouse and keyboard. SCF systems are based on the recognition that children with ADHD present with deficiencies in self-regulation, sustained attention, alternating attention, selective attention, and working memory. The child plays a series of interactive computer exercises which aim to improve skills in these areas. As children progress through the sessions, the software provides reinforcement for completing tasks with increased accuracy and rapidity and decreased impulsivity.

SCF interventions have been shown to lead to a decrease in parent-rated symptoms of ADHD (Klingberg et al, 2005; Shalev, Tsal, & Mevorach, 2007), such as inattentiveness, motor activity and disruptive behaviors (Klingberg, Forssberg, & Westerberg, 2002; Kotwal et al, 1996). Several studies present evidence suggesting that attention training systems with SCF may improve performance on working memory tasks (Klingberg et al, 2005; Klingberg et al, 2002; Kotwal, Burns, & Montgomery, 1996; Loo & Barkley, 2005; Monastra et al, 2005). Improvements have also been shown to generalize to conceptual reasoning, mathematical problem-solving, reading comprehension, and passage copying (Klingberg et al, 2005; Klingberg et al, 2002; Shalev et al, 2007). Research on SCF interventions has also suggested changes in brain activity: a study of 8 adults showed increased brain activity in areas of the brain related to working memory (Olsen, Westerberg, & Klingberg, 2004).

Purpose / Objective / Research Question / Focus of Study:
Description of the focus of the research.

Clinically significant attention problems among children present a significant obstacle to increasing student achievement. Computer-based attention training holds great promise as a way for schools to address this problem. The aim of this project is to evaluate the efficacy of two computer-based attention training systems in schools. One program uses neurofeedback (NFB) to train children with ADHD to focus on a task, and the other uses a Standard Computer Format (SCF) for cognitive retraining. We hypothesize that 1) both treatments will result in improvement in ADHD symptoms compared to a control condition; and 2) both treatments will result in improvement in academic outcomes compared to a control condition.

Setting:
Description of the research location.

This research is on-going and takes place in 19 elementary schools that accepted to participate in the project. The schools are part of two school systems in the greater Boston area. *The Newton Public School System* includes fifteen elementary schools and is located in a small suburban city. Minority populations are represented in the 4 urban elementary schools in the *Boston Public Schools*.

Population / Participants / Subjects:
Description of the participants in the study: who, how many, key features or characteristics.

Participants included in the study follow these criteria: 1) child in 2nd or 4th grade; 2) a diagnosis of ADHD (any subtype) by written report from the child's clinician; and 3) children must speak and understand English enough to follow the intervention protocol, though English need not be their first language. Exclusion criteria are: 1) a coexisting diagnosis of conduct disorder, pervasive developmental disorder, or other serious mental illness, and 2) IQ lower than 80. The Institutional Review Board of Tufts Medical Center / Tufts University reviewed and approved this study funded by the Institute of Education Sciences for a four-year study. See table 1, appendix B for participant demographics.

Intervention / Program / Practice:
Description of the intervention, program or practice, including details of administration and duration.

The neurofeedback intervention system used is commercially available and was chosen for several reasons: (1) the NFB component is directed at increased theta waves and decreased beta waves in the frontal cortex, which are the most frequently observed cortical deficits in children with ADHD (Lubar, 1991); (2) it uses EEG sensors that are embedded in a bicycle helmet, as opposed to EEG sensors placed directly on the scalp with wires, which significantly eases delivery in children. When the theta/beta ratio decreases, reflecting effective focusing, the dolphin character collects coins from a treasure chest and the child earns points. This feedback reinforces states of full attention. This system includes different tasks to train attention stamina, visual tracking (as required in the classroom), increased time-on-task, short-term memory and sequencing, and discriminatory processing. As the child advances, s/he progresses to more challenging tasks that include visual and auditory distractions, such as colorful shapes moving around on the screen and background noise.

The SCF intervention used is also commercially available and was chosen for several reasons: (1) it includes an extensive array of cognitive exercises that target many areas of attention as well as working memory; and (2) the ease of this system is especially well designed for delivery in a larger setting. The SCF system is designed to improve sustained concentration and working memory through a variety of specific interactive exercises manipulated with a standard computer mouse and keyboard. The exercises aim to maximize attention, decrease impulsivity, and train auditory and visual working memory. The tasks become more challenging as the participant progresses.

Before the interventions begin, each student’s classroom teacher reviews planned session times with the intervention Research Assistant (RA) in order to avoid affecting core academic instruction. Participants receive three 45-minute intervention sessions per week for a total of 40 intervention sessions, conducted at a 2:1 or 1:1 student-to-RA ratio. The sessions are completed over a five month period. RAs administer both interventions in the same way. A RA helps each child maintain attention by setting goals, offering prompts when the child becomes distracted, and evaluating progress. Small tangible incentives are provided at the end of each session, a larger incentive is received when the child reaches a new level, and a prize is won at the end of the 40 sessions.

Research Design:

Description of research design (e.g., qualitative case study, quasi-experimental design, secondary analysis, analytic essay, randomized field trial).

This study is designed as a randomized controlled field trial. Children are randomized via a computer random number generator into the three conditions (NFB, SCF, and WLC) stratified based on gender and medication status (see Figure 1, Appendix B). A control group is necessary as it is important to show that documented improvements in ADHD symptoms are associated with the computer interventions and are not attributable to other factors, e.g. maturation, general education, regression to the mean or off-protocol treatments. Inclusion of a waitlist group controls for such factors. Because WLC participants are not discouraged from pursuing standard community treatment, any benefit found for either intervention condition in comparison to WLC will represent an improvement over standard care. We provide the same computer-based interventions by random assignment to the children in the waitlist group after a one-year delay. Offering intervention to WLC increases the sample size available for analyses, which significantly improves our ability to detect treatment moderators.

In addition to offering the intervention to WLC to increase sample size, we also have two waves of data collection, each following identical enrollment and randomization procedures. Each year, we enroll incoming 2nd and 4th graders with diagnoses of ADHD, so that children who are in grades 1 & 3 during the 1st year of the study have the opportunity to enroll when they advance to grades 2 & 4 in the 2nd year of the study. One year after the initial intervention in each wave, children assigned to the WLC group are randomly assigned to complete one of the same two interventions (see Figure 1, Appendix B). Wave 1 enrollment, randomization, and intervention were completed in the 2009-2010 school year and wave 2 has started for the 2010-2011 school year. Reported here are preliminary results from 3 outcome measures from wave 1.

Data Collection and Analysis:

Description of the methods for collecting and analyzing data.

Assessment methods include paper-and-pencil checklists completed by parents, students and teachers, structured assessments of the child, and direct observations of classroom behavior (see Table 2, Appendix B). Constructs to be assessed include: a) ADHD symptoms, b) academic achievement, c) classroom performance, d) behavioral problems and impairment.

Parents, teachers, and children of the immediate intervention group complete a systematic assessment at three time points (before the intervention, immediately after the intervention, and 6 months later). The waitlist control group complete assessments at the same time points, with additional assessments immediately after their intervention and 6 months later. To help control for the possibility that participants would report improvement due to expectancy effects, we included several objective measures of functioning, including computer-based assessment of ADHD symptoms, classroom observations, and academic achievement.

A preliminary analysis of wave 1 variance from time 1 (before the intervention) and time 2 (after the intervention) was completed and is reported here for the Swanson, Kotkin, Agler, M-Flynn and Pelham Rating Scale-Teacher Version (T-SKAMP), Permanent Product Measure of Performance math achievement test (PERMP), and the Behavioral Observation of Students in Schools (BOSS). The BOSS, a double-blind classroom observation was conducted at three separate times for each student before and after the intervention.

Findings / Results:

Description of the main findings with specific details.

Wave 1 participants include 41 children diagnosed with ADHD in the 2nd and 4th grades. We conducted preliminary analyses of variance of the PERMP, T-SKAMP, and BOSS (see Tables 3 and 4, Appendix B). The NFB intervention group showed improvement on the number of math problems correct on the PERMP math test (p=0.03), indicating an increase in accuracy, as well as in increase in number of problems attempted on the PERMP math test (p=0.02), illustrating an increase in speed. The NFB intervention group also demonstrated a decrease in ADHD symptoms as reported by teachers on the T-SKAMP Attention scale (p=0.01). The SCF group showed improvement on the number of problems correct on the PERMP math test (p=0.01) indicating an increase in accuracy, and a trend towards decreased ADHD symptoms on the T-SKAMP. The WLC showed no significant effects on either the PERMP or the T-SKAMP. The BOSS showed a trend towards ADHD symptom reduction in the classroom setting.

Conclusions:

Description of conclusions, recommendations, and limitations based on findings.

Our preliminary data from a four-year study evaluating the efficacy of two computer-based attention training systems in schools shows significant results as well as promising trends. As this is a preliminary analysis of preliminary data we have not addressed all of the study's aims and have not yet compared data between the three intervention groups. Teacher report of ADHD symptoms, math achievement by students, and objective classroom observations for our first wave were analyzed. Our preliminary data on these outcome measures suggest that computer-based attention training programs offered in an elementary school setting may be effective in reducing symptoms of ADHD and improved math achievement. We hope that analysis of full data collected after the intervention of wave 2 will consolidate our findings and further explore the feasibility and effectiveness of computer –attention training as a method to support children with attention issues in schools.

Appendices

Not included in page count.

Appendix A. References

References are to be in APA version 6 format.

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Appendix B. Tables and Figures
Not included in page count.

Figure 1. Study Design

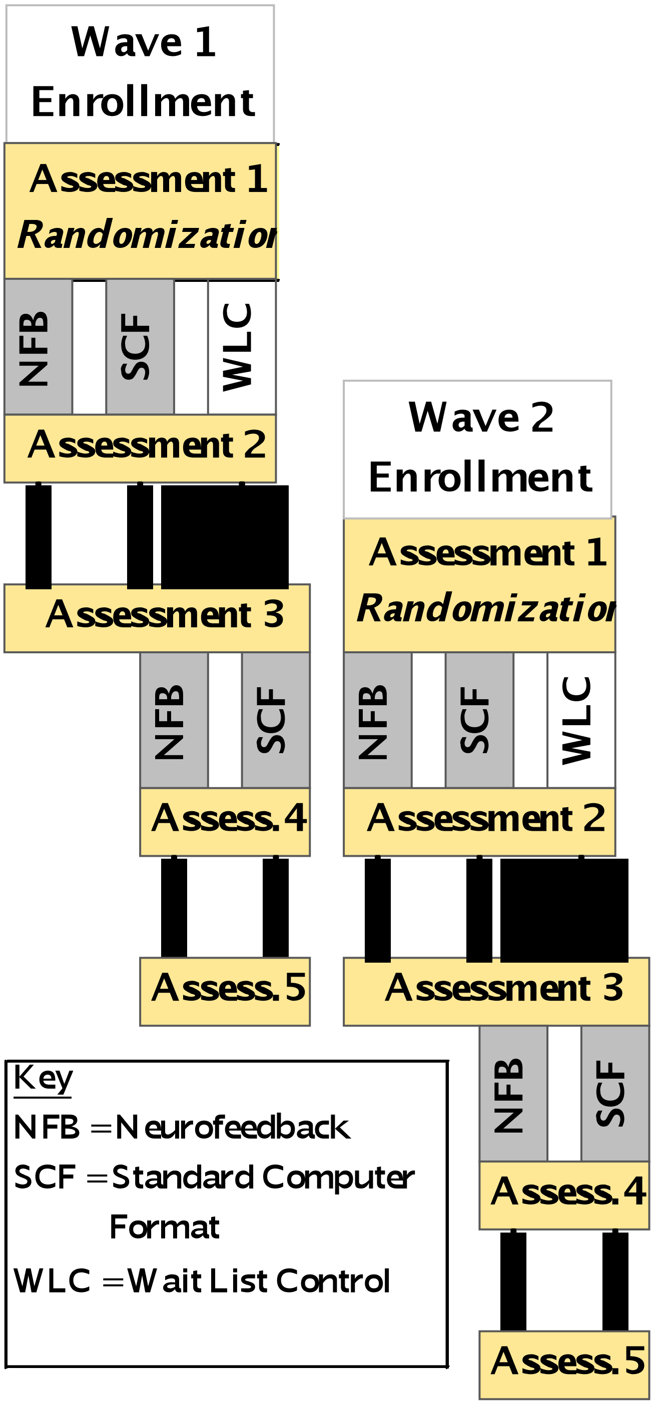

Table 1. Wave 1 Participant Demographics

Category	Participant Count
Sex	
Male	29
Female	12
Ethnicity	
Not Hispanic or Latino	23
Hispanic or Latino	4
Declined to Answer	14
Race*	
Asian	7
Black or African American	4
White	31
Declined to Answer	1
Family Income	
$9,999 or less	2
$10,000- $24,999	4
$25,000- $49,999	6
$50,000- $74,999	3
$75,000- $99,999	3
$100,000- $149,000	10
$150,000 or more	11
Declined to Answer	2

* Participants may report more than one race

Table 2. Outcome Measures

Instrument	Child	Parent	Teacher	Objective Observer
AIMSWeb (Spelling, Reading, and Writing)	✓			
Behavioral Observation of Students in Schools (BOSS)				✓
Behavior Rating Inventory of Executive Function (BRIEF)		✓	✓	
BROWN ADD Scales	✓			
Columbia Impairment Scale (CIS)		✓		
Conners 3rd Edition		✓	✓	
IVA+Plus Continuous Performance Test	✓			
Permanent Product Measure of Performance (PERMP)	✓			
Swanson, Kotkin, Agler, M-Flynn and Pelham Scale (SKAMP)			✓	

Table 3. PERMP Math Test Preliminary Data

	Mean		Effect Size
	Time 1	Time 2	
PERMP Number Correct (Accuracy)			
NFB	103.5 (47.83)	119.67 (47.28)	**-0.34****
SCF	96.69 (44.21)	109.23 (51.28)	**-0.26****
WLC	99.73 (73.46)	100.87 (67.92)	-0.016
PERMP Number Attempted (Speed)			
NFB	114.17 (51.38)	128.42 (45.23)	**-0.29**
SCF	103.85 (39.63)	111.69 (50.32)	-0.17*
WLC	105.8 (70.85)	104.33 (65.16)	0.022

Standard Deviations in parenthesis
* $p < 0.10$, ** $p < 0.05$
bold = medium to large effect size

Table 4. Teacher SKAMP (ADHD Symptoms) Preliminary Data

	Mean		Effect Size
	Time 1	Time 2	
T-SKAMP Total			
NFB	16.08 (7.90)	12.33 (6.89)	**0.51****
SCF	17.14 (8.49)	15.43 (7.70)	**0.21***
WLC	15.43 (7.01)	15.5 (6.45)	-0.01
T-SKAMP Attention Average			
NFB	1.85 (.86)	1.36 (.76)	**0.60*****
SCF	1.89 (.90)	1.75 (.82)	0.16
WLC	1.82 (.87)	1.79 (.74)	0.037
T-SKAMP Deportment Average			
NFB	1.21 (.83)	.96 (.87)	**0.29***
SCF	1.45 (0.97)	1.23 (.95)	**0.23****
WLC	1.13 (.72)	1.18 (.80)	-0.066

Standard Deviations in parenthesis
* $p < 0.10$,** $p < 0.05$, *** $p < 0.01$
bold = medium to large effect size